



Edible films and coatings based on starch/gelatin: Film properties and effect of coatings on quality of refrigerated Red Crimson grapes



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ABSTRACT

Edible films have been studied as potential substitutes for conventional plastics in food packaging. Their development provides a new alternative for the application of hydrocolloids, following global trends of environmental preservation. Taking this into account, the aim of this study was to develop and evaluate physicochemical properties (thickness, solubility in water and acid, water vapor permeability, opacity, tensile strength and elongation at break) of composite films based on corn starch (native, modified waxy or waxy) and gelatin, plasticized with glycerol or sorbitol. After this initial screening, the formulation presenting the physicochemical properties more appropriate was applied as an edible composite coating onto Red Crimson grapes to extend the shelf-life. The addition of gelatin significantly increased mechanical strength, solubility in water, permeability to water vapor, and thickness of the biofilms, while also decreasing the opacity. Composite films prepared with sorbitol had significantly lower permeability to water vapor and higher tensile strength than the films plasticized with glycerol. Improved appearance was observed in coated grapes after 21 days storage under refrigerated conditions, which had lower weight loss than the control group. Sensory evaluation showed that all the coatings did not affect acceptability scores.

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1. Introduction

Edible films and coatings are thin layers of edible materials applied on food products that play an important role in their preservation, distribution and marketing (Bourtoom, 2008; Falguera et al., 2011; Jridi et al., 2013). Several important parameters for the application of such films should be properly studied (mechanical, barrier and thermal properties, water solubility) in order to replace the widely used polymers in the packaging industry, which are mostly of petrochemical origin. Among the natural polymers able to form edible films, starch and gelatin are potential sources. Corn starch is a polysaccharide widely produced around the world (Laycock and Halley, 2014) and gelatin differs from other hydrocolloids as a fully digestible protein, containing nearly all the essential amino acids, except tryptophan (Duconseille et al., 2015). An edible

film (EF) is a pre-formed, thin layer, made of edible material, which, once formed, can be placed on or between food components, while an edible coating (EC) is a thin layer of edible material formed as a coating on a food product (McHugh, 2000). Edible coatings can be applied by dipping products in coating materials and then allowing excess coating to drain as it dries and solidifies (Baldwin et al., 2011).

Studies considering alternative systems for food protection that utilize biopolymers have increased significantly in the last years because these materials are entirely biodegradable and often edible and have few adverse environmental effects (Fadini et al., 2013; Martelli and Laurindo, 2012). In this sense, edible films and coatings are receiving much attention as an efficient way to protect fresh and/or minimally processed vegetables from degradation during storage. They can be used to control the permeability to water, oxygen and carbon dioxide, as well as lipid permeability in a food system (Espinel Villacres et al., 2014; Galus et al., 2012; Krochta and DeMulderJohnston, 1997).

EC can offer several advantages to the fresh fruit and vegetable industry such as improvement in the retention of color, acids, sugar and flavor components, the maintenance of quality during

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shipping and storage, the reduction of storage disorders and improved consumer appeal (Nisperos-Carriedo et al., 1992). These advantages assume that EC could have a selective permeability to oxygen, carbon dioxide, water vapor and solute. This simple and straightforward approach works for a variety of products considering that EC may also contain active agents such as antimicrobials and antioxidants, which may extend the shelf-life of a product (Jiang et al., 2012; Ponce et al., 2008) or probiotics (López de Lacey et al., 2012).

Chitosan, starch, cellulose, alginate, carrageenan, gelatin, zein, gluten, whey, carnauba, beeswax and fatty acids are the most commonly used compounds to form edible coatings (Baldwin et al., 2011; de Aquino et al., 2015; Shit and Shah, 2014). Some examples of edible coatings in commercial usage include the coverage of fruits (Correa-Betanzo et al., 2011; de Aquino et al., 2015; Farias et al., 2012), chocolate and cassava products (Castro Freitas et al., 2009; Fadini et al., 2013).

The aim of this work was to develop and characterize edible films based on blends of different corn starches and plasticizers for application on the surface of Red Crimson grapes in order to provide protection and brightness. The coating effect on the shelf-life of these grapes after long-term refrigeration was also evaluated. A physicochemical screening of various coating films was performed to optimize the final composition of biofilms to be included in the grapes.

2. Materials and methods

2.1. Materials

Native corn starch (AMISOL[®] 3408), native waxy corn starch (AMISOL[®] 4000, around 100% amylopectin) and modified waxy corn starch (FLUIDEX[®] SS-22), were kindly supplied by Corn Products (Brazil). These starches differed in amylose content and amylopectin. Gelatin type A (Leiner Davis Gelatin), glycerol (Synth) and sorbitol (Getec) were used as received. Polypropylene films were obtained from Braskem (Brazil).

2.2. Preparation of GEL and starch solutions

The filmogenic gelatin (GEL) solution was obtained by the hydration of 10 g of GEL in 100 mL of distilled water for 1 h at room temperature. After this period, the solution was heated at 70 °C and maintained at this temperature for 10 min. The plasticizer (sorbitol or glycerol) (100 g/kg of the GEL) was then added with constant gentle stirring to prevent air bubbles and gelatin denaturation.

The starch solutions were obtained by dispersing 3 or 5 g of corn starch (native, waxy or modified waxy) in 100 mL of distilled water. After complete dispersion, 100 g/kg (for each gram of starch, 0.1 g of plasticizer was added) of plasticizer (sorbitol or glycerol) was added. The resulting solution was heated at 70 °C (waxy and modified waxy starch) and 85 °C (native starch) for 10 min under constant stirring.

2.3. Preparation of edible films

In order to obtain edible films, the starch and GEL solutions were mixed in different ratios: 4:1 (80 wt-% of starch and 20 wt-% of GEL), 1:1 and 1:4. Aliquots of 20 mL of the resulting solution were added in Petri dishes (diameter of 11.8 cm). The films were then dried at room temperature (25 °C) for 24 h and stored at this temperature and 52% relative humidity, for 48 h, prior to characterization. The identification codes and composition of the samples are shown in Table 1.

Table 1

Sample codes and composition.

Sample code	WCS (g/kg)	MOD (g/kg)	NA (g/kg)	GEL (g/kg)
3 WCS/GEL/XL	30	–	–	100
5 WCS/GEL/ XL	50	–	–	100
3 MOD/GEL/XL	–	30	–	100
5 MOD/GEL/XL	–	50	–	100
3 NA/GEL/XL	–	–	30	100
5 NA/GEL/XL	–	–	50	100

NA, native corn starch; WCS, waxy corn starch; MOD, modified waxy corn starch; GEL, gelatin; XL, plasticizer (100 g/kg of macromolecules), which can be glycerol (GLY) or sorbitol (SOR).

2.4. Characterization of edible films

2.4.1. Visual aspect

Visual and tactile analysis were performed in order to select the homogeneous bioplastics, which presented a uniform color, no insoluble gelatin particles, flexible on handling and with no cracks or zones prone to breakage.

2.4.2. Film thickness

Film thickness was measured using a Mitutoyo micrometer (Model MDC-25M, MFG/Japan). The final value represented the average of 10 random measurements taken at different parts of the film.

2.4.3. Opacity

The opacity of the film was determined using a Hunterlab colorimeter (Colorquest II, Fairfax, USA). The determinations were carried out in triplicate after calibration of the colorimeter with a standard white background and a standard black background. The values for opacity were calculated according to the following equation:

$$Op = \left(\frac{Op_N}{Op_B} \right) \times 100$$

where Op = opacity of the bioplastic (%);

Op_N = opacity of the bioplastic against a black background;

Op_B = opacity of the bioplastic against a white background.

2.4.4. Water and acid solubility

The bioplastic solubility in water was determined according to the method proposed by Gontard et al. (1994). Briefly, 2 cm diameter samples were cut from the bioplastics ($n = 3$). The initial dry weight of the samples was obtained by drying them at 105 °C for 24 h in an air circulation oven (TECNAL TE 394/2, Piracicaba, Brazil). After the first weighing, the samples were immersed in a flask containing 50 mL of distilled water, and maintained under slow agitation for 24 h. The swollen samples were then removed and dried again at 105 °C for 24 h before determining their final dry weight.

The solubility of the samples in acid medium was tested by initially preparing them as described in Section 2.4.4. After determining their initial dry weight, the samples were immersed in a beaker containing hydrochloric acid (1 M) for 24 h, and then dried and weighed to determine their final dry weight.

2.4.5. Water vapor permeability

Water vapor permeability (WVP) of films was measured according to a modified ASTM E96 standard test method (Espinel Villacres et al., 2014). The film samples were fixed in aluminum cells containing solid calcium chloride (relative humidity near to 0.01% at 25 °C), and sealed with paraffin to ensure water migrating only through the exposed area of the film. The permeation cells were placed in desiccators kept at 25 °C and 75% relative humidity

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